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SHORT COMMUNICATION

Diet of *Natalus mexicanus* (Chiroptera, Natalidae) in a semi-evergreen forest in Oaxaca, Mexico

Dieta de *Natalus mexicanus* (Chiroptera, Natalidae) em uma floresta perenifólia em Oaxaca, México

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Abstract

We investigated the diet composition of *Natalus mexicanus* in a semi-evergreen forest in the state of Oaxaca, in the southeast of Mexico, using fecal analysis. The diet was composed of eight arthropod orders, the most abundant and important preys being members of the orders Diptera, Coleoptera, Hemiptera, and Hymenoptera. We did not observe significant differences in diet composition between males and females or in proportions consumed by the bats and those obtained through collections with light traps. In the study area, *N. mexicanus* is a species with a generalist opportunist diet.

Resumo

Investigamos a composição da dieta de *Natalus mexicanus* em uma floresta perenifólia no estado de Oaxaca, no sudeste do México, utilizando análise fecal. A dieta foi composta por oito ordens de artrópodes, sendo as presas mais abundantes e importantes foram membros das ordens Diptera, Coleoptera, Hemiptera e Hymenoptera. Não observamos diferenças significativas na composição da dieta entre machos e fêmeas ou nas proporções consumidas pelos morcegos e aquelas obtidas através de coletas com armadilha luminosa. Na área de estudo, *N. mexicanus* é uma espécie com dieta oportunista generalista.

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PENSOFT

Keywords
Diptera, diversity, Coleoptera, Hemiptera, Hymenoptera, Insecta

Palavras-chave
Diptera, Diversidade, Coleópteros, Hemípteros, Himenópteros, Insecta

The family Natalidae includes small bats from the tropics of the New World that consume insects of small size. The Mexican greater funnel-eared bat *Natalus mexicanus* Miller, 1902, the only species of the family Natalidae that occurs in Mexico (López-Wilchis et al. 2012), is distributed from the north of Mexico to Panama (Tejedor 2011; López-Wilchis et al. 2012). In Mexico, it is distributed in the Pacific coastal region, from the west of Sonora and including the Baja California Peninsula, and in the Gulf of Mexico, from the center of Nuevo León to the Yucatan Peninsula (Téllez-Girón and Ceballos 2005). It is mainly found in dry, seasonal, and wet forests, thorn scrubland, and secondary vegetation. Many aspects of the natural history of this species are unknown, such as the composition of its diet (Torres-Flores and López-Wilchis 2018).

Studies of bat diets have used analyses of stomach contents, feces, parts of prey remains, and direct observations (Whitaker et al. 2009), with the most common being stomach content and fecal analyses. In the present study, we carried out fecal analysis since this way we could obtain a higher number of samples compared to prey remains and stomach contents, as well as relatively more accurate results on the orders consumed by the bats. It is also a less destructive sampling method (Gardner 1977; Rabinowitz and Tuttle 1982; Kunz and Whitaker 1983; Whitaker et al. 2009). This technique consists of collecting feces, analyzing it by separating exoskeletons from other dirty, and then identifying large pieces of these exoskeletons such as legs, antennas, eyes, and wings for the identification and quantification of prey abundance (Whitaker et al. 2009).It is known that *N. mexicanus* feeds on small insects, mainly of the orders Diptera, Coleoptera, and Hemiptera (Kunz et al. 2011). There is only one published study on the diet of *N. mexicanus* in a dry tropical forest in the state of Colima, Mexico (Torres-Flores and López-Wilchis 2018). Thus, the objective of the present study was to describe the diet of *N. mexicanus*, as well as to evaluate whether there is variation in the frequencies of preys consumed between males and females, in a semi-evergreen forest.

Feces of *N. mexicanus* were collected in the surroundings of the cave El Apanguito (15°52'58"N, 96°21'13.2"W, 715 m.a.s.l.). It is located in the municipality of Santa Maria Huatulco, in the south-southeast of the state of Oaxaca, region of Costa, in the southeast of Mexico. The predominant vegetation is semi-evergreen forest mixed with coffee plantations. The climate is hot sub-humid with rainfall in the summer (monthly average of the season 216.5 mm) and the annual temperature is 28 °C. Six monthly samplings were carried out from August to October 2016 and from December to February 2017.

The diet composition of *N. mexicanus* was investigated using fecal analysis. For bat capture we placed a 7.5 m mobile harp trap at the entrance of the roost (Kunz and Kurta 1988) from 18h to 24h. Captured specimens were placed in cloth bags for one hour and the obtained feces were stored in plastic microtubes with alcohol (Whitaker et al. 2009) and labelled with the number of the fecal sample. For each bat captured, conventional external morphometric measurements (total length, tail length, leg length, right ear and forearm length and weight), age, sex and reproductive condition, were taken. Bats were released at the same site where they were captured.

Each fecal sample was dried at room temperature and the number of pellets per individual was counted. Samples were weighed in an analytical balance, washed in 70% alcohol in a Petri dish, and separated with a dissecting needle, taking care not to damage the parts of arthropods in the sample. Each sample was observed and analyzed under a stereomicroscope. Each arthropod part that could be identified was compared with an entomological reference collection obtained at the same site during the sampling season.

Arthropod collection. A reference collection was obtained in order to identify the prey (Whitaker et al. 2009). We carried out a photophilic collection by placing two light-traps, which consisted of a screen-shaped white sheet with a mixed light source (white light and black light) and with a white LED light. The traps were placed under the trees because it is in this area where *N. mexicanus* forages, and also to obtain a greater reflection of the light. A piece of cloth was placed underneath to collect arthropods that fell to the ground; traps were active for three and a half hours during all the nights of sampling (Kunz 1988; Márquez 2005). All arthropods caught in the light-trap were collected and preserved in 70% ethanol for identification using specialized literature.

Data analysis. For each insect order recorded in the feces, we calculated the relative abundance (RA) and the importance index (II) modified by García-Rodriguez and Aurioles-Gamboa (2004), both expressed as percentages:

$$\mathrm{RA} = \sum_{j=1}^{U} n_{ij} \,/\, \sum_{j=1}^{U} n_j$$

and

$$\mathrm{II} = \frac{1}{U} \sum_{j=1}^{U} n_{ij} \,/\, n_j$$

where n_{ik} = mínimun number of remains of the order i in the sample j, n_j = total number of remains in the sample j and U = total number of samples.

We compared the consumption of the different orders between males and females with a Mann-Whitney U test, and evaluated selectivity by comparing the differences between the proportions consumed by the bats and those from the collections using a Chi-squared test. To evaluate the diet diversity of *N. mexicanus*,

Table 1. Relative abundance (RA) and importance index (II) of insect orders consumed by *Natalus mexicanus* in a semi-evergreen forest in Oaxaca, Mexico. Both measures are expressed as percentages.

Order	RA	II
Diptera	29.45	38.62
Coleoptera	26.99	27.22
Hemiptera	12.88	13.10
Hymenoptera	10.43	10.80
Psocoptera	2.45	3.65
Lepidoptera	3.07	3.43
Ephemeroptera	1.84	2.21
Dermaptera	0.61	0.96

we used Simpson's reciprocal index ($1/D_S$) because it is less sensitive to variations in sample size and gives less weight to rare taxa. This index uses values from 1 to the sample number of species, or in this case, the number of insect orders found in feces. Trophic breadth was analyzed with the Levins index, which takes values from 0 to 1: values higher than 0.6 indicate a generalist diet and lower values indicate a specialist diet (Krebs 1999).

A sampling effort of 540 meters·trap/hour resulted in the collection and analysis of 23 fecal samples of *N. mexicanus*, 10 from females and 17 from males, where we observed a total of 163 insect remains, 143 of which could be identified to order level. Both sexes' diet was composed of eight arthropod orders, whereas 15 orders were recorded in the collections. The most abundant and important prey were members of the orders Diptera (RA = 29.45, II = 38.62), Coleoptera (RA = 26.99, II = 27.22), Hemiptera (RA = 12.88, II = 13.1), and Hymenoptera (RA = 10.43, II = 10.8%). Members from the other four insect orders showed abundances of less than 10% and an importance of less than 5% (Table 1). We also found seeds of *Piper* spp. and eggs of unidentified insects, which presented very low frequency and importance. There were no significant differences in consumption frequencies between males and females ($z = -1.4402$, $P = 0.149812$). There were also no significant differences in proportions between *N. mexicanus* consumption and insect collections (Chi-squared = 0.1383, gl = 7, $P = 0.9993$), which is supported by a Levin's dietary breadth value of 0.941, indicating that this is a generalist species. In the case of diversity, we obtained a Simpson's reciprocal index value of 3.91; this is a medium value since the maximum obtainable value is eight, which is the number of orders we recorded in the diet.

Natalus mexicanus exhibits a diet composed of members of eight orders: Coleoptera, Dermaptera, Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Lepidoptera, and Psocoptera; where four of them were the most abundant and important. Even though there are only a few studies on the diet of *N. mexicanus*, it is known that this species feeds on small insects (Kunz et al. 2011). In a dry tropical forest in the state of Colima, Mexico, the diet of *N. mexicanus* was found to be composed mainly of arachnids, which represented over half of the food volume consumed throughout the year, and it is a resource that is not commonly used by other species of bats,

which likely allows for coexistence with other insectivorous species (Torres-Flores and López-Wilchis 2018). In that same study, the diet of *N. mexicanus* was complemented – in order of importance - with small lepidopterans, coleopterans, dipterans and hymenopterans. In contrast, the most important components of the diet in our study were Diptera and Coleoptera, and we did not record any arachnids in the fecal samples. This is probably because the abundance of arachnids is naturally low in the study area, since this group represented only 0.54% of the collected organisms in the light traps, although this may also be due to the collection method used, which favors insects that are attracted to light. Spider diversity is significantly correlated with tree cover and diversity of plant forms (Pinkus et al. 2005), and species richness is significantly higher in preserved sites (Maya-Morales et al. 2012). The vegetation in the study of Colima was dry tropical forest with a large part of the original vegetation modified by the establishment of cattle ranches and agricultural fields (Torres-Flores et al. 2012), whereas the surroundings of the El Apanguito cave exhibit a more humid climate, semi-evergreen forest, and even though there are some cropping areas in the vicinity, these are mostly rustic coffee plantations with very little management and the presence of many of the original tree elements.

In the case of the order Coleoptera, it is likely that their high abundance in feces is, at least partially, the result of the hardness of their exoskeleton, which is more difficult to digest than the remains of members of other orders. For example, beetles were about 3.2 times harder than moths of the same body size (Freeman and Lemen 2007)). In addition, when it comes to large-sized individuals, they can leave more than one part in the sample, which can also contribute to overrepresentation, rather than preference by *N. mexicanus*.

We did not find differences in diet composition between males and females in the study area. However, even though it has been rarely evaluated in insectivorous bat species, such differences have been observed in the European free-tailed bat *Tadarida teniotis* (Mata et al. 2016), while for *T. brasiliensis* no significant differences were found (Kunz et al. 1995; Lee and Mccracken 2005; Gamboa Alurralde and Díaz 2018). In the case of nectarivorous bats of the genus *Glossophaga*, where differences in the diet of males and females have also been observed, these are probably due to females feeding on the closest available resource while males move larger distances to find other feeding sites (Álvarez and Sánchez-Casas 1999), particularly when females are gravid and their food-searching area is more restricted than that of males because of a higher energetic cost of moving to other sites (Sosa and Soriano 1996). We did not obtain any samples of gravid or lactating females in our study, so we could not assess the presence of these differences in *N. mexicanus*.

In the case of diversity and breadth of the diet, we found that *N. mexicanus* exhibits moderate diversity and a generalist diet. Previous studies with insectivorous species suggest that species of small size, like *N. mexicanus*, fly at low speeds and, thus, encounter rates with many prey types are low and individuals are not expected to be very selective (Pulliam 1974). Even though there are no studies on flying speeds, natalid bats are very small and with good maneuverability, which allows

them to occupy dense spaces (Norberg and Rayner 1987). A large wing surface, average aspect ratio, extremely low wing loading, and wingtips average in length and very rounded are characteristics that result in extremely slow and maneuverable flight. Its flight, along with that of other representatives of the family Thyropteridae, has been described as fluttering similar to that of a moth (Kunz et al. 2011).

The results of the present study and its differences with other studies show that, in the area studied, *Natalus mexicanus* is an opportunistic predator, with a low diversity in its diet, and whose main prey are Diptera, Coleoptera, and Hymenoptera.

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